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Optimization of Wear Resistance Testing of Austempered Ductile Iron

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A B S T R A C T

The present study experimentally shows the wear resistance of the Ductile iron. The wear resistance can be improved by changing the microstructure (using heat treatment procss called Austemperin). Austempering can be done at different temperatures. Heat treatment can be done by the two process they are single-step Austempering, two-step Austempering process. Ductile iron is a group of irons that exhibit high strength , flexibility , durability , and elasticity due to their unique microstructure. In Ductile iron , graphite is in the form of nodules rather than fakes as in grey iron. Ductile iron has a greater strength and ductility than grey iron. Ductile iron pipe is resilient, safe and reliable with service life of over 100 years.Applications of ADI for heavy section castings have greatly increased recently. The difficulty of obtaining the requisite microstructures grows as casting section size increases because a slower cooling rate follows.

Keywords: Austempering , Pearlite , Ferrite , Graphite Nodules , Ausferrrite

Introduction

Due to its distinct microstructure, ductile iron, also known as spheroidal iron or nodular iron, is a class of irons that exhibits exceptional strength, flexibility, durability, and elasticity. Cast ductile iron can be bent, twisted, or deformed without cracking because it often contains more than 3% carbon. Its mechanical qualities are significantly superior to those of typical cast irons and are comparable to those of steel. Although steel or iron waste can be used to make ductile iron, pig iron is the main source of infeed for the majority of contemporary ductile iron foundries. Pig iron is the predominant form of iron produced in a blast furnace and comprises more than 90% iron. The phrase "pig iron" came from the antiquated practise of pouring blast furnace iron into moulds positioned in sand beds so they could receive feed from a single runner. Designers can benefit from ductile iron in a number of ways: Ductile iron can be cast and machined with ease. Its strength to weight ratio is outstanding. Steel may be produced for a lot less money than ductile iron. It is better at being cast and machined. Ductile iron offers a remarkable balance of durability, affordability, and robustness to designers. Gray iron is less ductile and strong than ductile iron. These characteristics enable its efficient usage in a number of industrial applications, such as pipe,

Heat treatment known as austempering is used on ferrous metals, most notably steel and ductile iron. While it creates a microstructure of bainite in steel, ausferrite, a combination of acicular ferrite and high-carbon stabilized austenite, is created in cast irons. It is mostly used to enhance mechanical properties or lessen or completely get rid of distortion. Both the procedure and the resulting micro structure define Austempering. When standard austempering process parameters are applied to an unsuitable material, bainite or ausferrite are not formed, therefore the finished product cannot be referred to as austempered. Other techniques can also be used to create both microstructures. They could be made as-cast or air cooled with the right alloy content, for instance. Moreover, these materials are not mentioned

Due to its outstanding combination of low cost, high strength-to-weight ratio, toughness, fatigue strength, and wear resistance, austempered ductile cast iron (ADI) has drawn increased attention. This is because ADI combines acicular ferrite and carbon-stabilized austenite. Changes in alloying additives and heat treatment settings could alter the microstructure. To give the requisite hardenability, alloying is done. The silicon concentration of the ductile iron reduces carbide production during bainitic reactions. Ferrite with poor carbon solubility is produced when carbon deposition is permitted in the austenitic matrix. Austenite accumulates carbon until it is stable at normal temperature. When austenite (transforms into carbon-stabilized austenite, this is referred to as the primary reaction (or stage I).

Applications of ADI for heavy section castings have greatly increased recently. The difficulty of obtaining the requisite microstructures grows as casting section size increases because a slower cooling rate follows. With greater section thicknesses, the nodule count likewise declines. Micro-shrinkage, voids, graphite degradation, carbide development, and alloying element segregation are additional imperfections that can occur. Therefore, it is important to keep an eye on the casting variables, such as hot metal treatment, inoculation, tapping and pouring temperature, gating, and feeding system, in order to prevent or reduce elemental segregation. The final microstructure is mostly determined by the heat treatment parameters of austenitizing time and temperature. The shortest amount of time is required to heat the entire section to the necessary temperature during the austenitizing process . The duration of the austenitizing process depends on the metal's chemistry, the temperature at which it is done, and the number of nodules. Austempering Temperature: A high austempering temperature of 350–400 °C is chosen to produce ADI with low strength and hardness, but high elongation and fracture toughness, as this produces higher amounts of carbon-stabilized austenite (20–40%) . In contrast, a low austempering temperature of 350 °C produces ADI with high strength and wear resistance but low fracture toughness.

Short austempering times result in final structures with high hardness but low ductility and fracture toughness. Too much time spent austempering encourages the secondary reaction, which lowers strength, ductility, and fracture toughness. Even at the greatest austempering temperature (400 °C), it only takes 30 minutes to generate ausferrite; nevertheless, it takes considerably longer (about 4 hours).

Several researches have investigated the wear resistance of ADI: The wear resistance increases with a drop in austempering temperature as a result of the creation of an oxide coating and a high carbon martensitic surface structure. Because of strain-induced martensite, the laser-hardened ADI displayed superior wear resistance than regular ADI. It was discovered while researching the lubricated sliding wear behaviour that the wear resistance rises as the austenitizing and austempering temperatures fall. Wear resistance is increased by reduced bainite and carbon-retained austenite. The creation of a duplex structure, specifically lower bainite and high carbon-stabilized austenite, was described as the effect of two-step austempering operations on wear resistance.

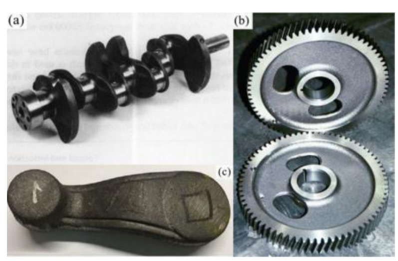

Fig 1 ADI applications (a) ADI crankshaft(b)ADI driving gear(c)ADI pitman arm.

High strength, ductility, and toughness are combined with good wear resistance and machinability to create austempered ductile iron (ADI), which has shown to be an outstanding material. These qualities can be obtained with an appropriate heat treatment that produces the ideal microstructure for a particular chemical composition. An investigation has been done in this publication. ADI alloyed with 0.45% Cu and austempered at various temperatures and durations. The development of fracture mode and microstructure during these treatments have been discovered using X-ray diffraction, light, and scanning electron microscopy. Analysis, Strength, elongation, and impact energy were demonstrated to be highly dependent on the amount of bainitic ferrite and the amount of retained austenite.

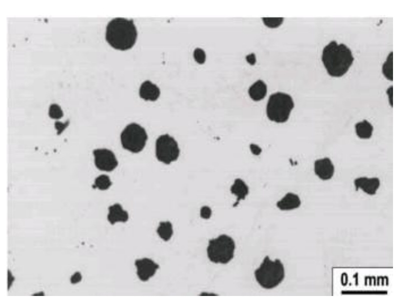

Fig 2 Microstructure of as-cast specimen.

Austempered ductile iron (ADI) has been used in a variety of applications because it combines high strength, toughness, and superior wear resistance with the low price. Moreover, ADI has gained a lot of attention in the research literature. ADI's mechanical characteristics are determined by the austemperped microstructure, which is a function in turn of temperature and time austempering. The focus of cent ADI research has been on the impact of characteristics and microstructure of alloying elements and restrained reaction. As a component of alloys. The phase diagram's austenite zone is widened by copper. When austenitizing , boosting both transformation rates method and the matrix's carbon concentration.

3 Materials & Methodology

Experimentation Setup & Equipment Used

Pin on Disk Test:

Friction and wear (typically wear rates and wear resistance) characterization of materials is typically performed using various types of tribometers, while pin on disk test being probably one of the most common. The popularity of the method is due to its relative simplicity and abundance of the tribological contacts that can be well described by the a simple pin on disk motion: from dry contacts of bolt screws to rail wheels to rail contact and to lubricated contact of biological implants.

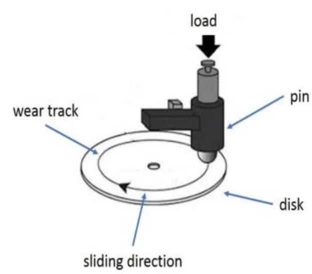

Fig3 : Pin on Disk Test

Pin on Disctribometer:

A tribometer is a device that measures tribological properties such as coefficient of friction, frictional force, and wear volume. Several arrangements are present based on the contact arrangement: Four ball, three ball, pin on disc, block on ring, twin disc, bouncing ball.

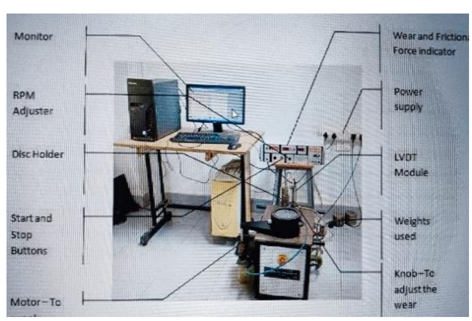

Fig 4 shows the Pin on Disc Tribometer

Schematically, the pin on disk test is depicted in the figure above. The stationary pin is pressed against rotating disk under the given load. The pin can be of any shape, however, the most popular shapes are spherical (ball or lens) or cylindrical due to ease of alignment of such pins (flat pins are typically subject to certain misalignment which can lead to non-uniform loading and difficulties for theoretical analysis). During the test, the friction force, wear and temperature are continuously monitored. A typical friction curve measurement recorded on a pin on disk apparatus is shown in the figure below:

As can be seen form the figure, at the start of the test, the measured coefficient of friction (COF) is high and with further progress drops. This behavior is typical friction measurements and is attributed to a running-in phenomenon. During the running-in, the surface topography changes, chemical reactions takes place until the system comes to a steady-state state. This steady state COF is then usually reported. The test can be performed in dry and lubricated conditions. In lubricated case, the pin is typically submerged in the lubricant bath, as shown in the figure below.

Test parameters :

1Load

2 Track diameter

3 Time

4 Rotational Spee

5 Sliding distance

- **Load:** Value of the Force (in newton) acting at the contact. It is the product of mass (Kg) of the load and acceleration due to gravity .
- **Track diameter:** The distance from the center of disc to the pin contact is called the Track radius. Track diameter is double to the Track radius.
- **Time:** Time taken to complete the test on Pin on disc tribometer based on Taguchi conditions.
- **Rotational speed:** Number of rotations at which the disc rotates per unit interval of time . Mostly consider the Rotational speed in RPM.
- **Sliding Distance** : Sliding Distance is the distance travelled by pin on the disc at a certain speed and time. The sliding distance was calculated for each of the runs.
  Sliding Distance (in m) = π*D*N*T/60 **D**- Track Día in mm **N**-Speed in rpm &**T**- time.

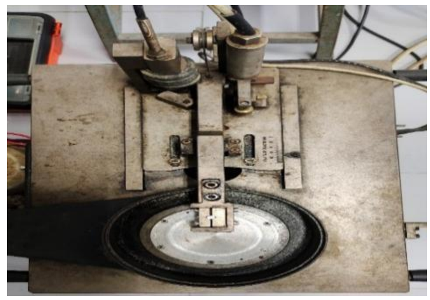

Fig 5 pin-on disc machine.

Table 1 - chemical composition

Elements	**Wight(%)**
Carbon	3.36
Silicon	2.95
Copper	0.59
Nickel	0.76
Manganese	0.40
Iron(balanced)	91.93
Carbon Equivalent	4.34

Heat Treatment process:

The austempering process was carried out in a specially designed twin chamber austempering vertical furnace. The pins were austenitized for 60min at 900 C in furnace. For two-step austempering process, specimens were then quenched into a salt bath at 250 C (above martensitic start temperature). After stabilization at 250 C,the salt bath temperature was steadily increased to 350 C ,400 C ,450 C and the samples were austempered for 120 min. For conventional austempering process , specimens was directly quenched into salt bath at 350 C ,400 C ,450 C and soaked for 120min in the salt bath. After soaking, the specimens were air-cooled to room temperature. For single - step austempering process, specimens were then quenched into a salt bath at 350 C ,400 C ,450 C and the samples were austempered for 120 min.

Reduction of diameter of pins:

Initial diameter of the pin is 10mm.we need to reduce it to 8mm. The length of the pin is 24mm. The pin need to be hold in the Hydraulic chuck, The tools we used to reduce the diameter are roughing tool and finishing tool. The half portion of the pin kept outside of the chuck. After reducing the diameter turn the pin and fix it in the chuck. The required diameter is obtained.

Fig 6 Reducing Diameter in CNC machine.

Cleaning the pin with isopropyl alcohol .

Take the initial weights of the pins.

Experimental Procedure :

- The disc and pin needs to be fixed to the wear test module with the help of suitable Allen keys.
- With the help of Allen key adjust the wear track diameter.
- Connect the power and switch on the module and the Software system attached to it.
- Open and Create the required Data file in WINDUCOMM Software.
- Lift the pin contact and adjust the speed by turning the knob and also press the time buttons to set the required time.
- Add the required loads and adjust the LVDT module readings(wear and friction force) by adjusting the rotating screws.
- Ensure all the experiment conditions are set and begin the Experiment by clicking "Run continuously" and then press start by simultaneously clicking Start on both software and wear test module.
- Record the Data and save the graphs.
- Record the values of Coefficient of friction by using View file option.

Conclusion:

The wear resistance increases with a drop in austempering temperature as a result of the creation of an oxide coating and a high carbon martensitic surface structure. Because of strain-induced martensite, the laser-hardened ADI displayed superior wear resistance than regular ADI. It was discovered while researching the lubricated sliding wear behaviour that the wear resistance rises as the austenitizing and austempering temperatures fall. Wear resistance is increased by reduced bainite and carbon-retained austenite.

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